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Paper Session I-B - Launch Site Comparison Between the Earth, the Moon and Mars

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LAUNCH SITE COMPARISON BETWEEN THE EARTH, THE MOON, AND MARS

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Abstract

Space flight will need to evolve rapidly in sophistication and accomplishment. The need to develop affordable long term operations increases accordingly. As the Space Exploration Initiative (SEI) Program moves forward, human exploration of the Moon and Mars will require vehicles with improved capabilities. The payloads envisioned require launch vehicles, support equipment, facilities and fuels which mandate a quantum leap in our launch operations capabilities. Our knowledge of Earth based launch site processing, mission support and integrated logistics will drive vehicle designs for lunar and martian surface operations. Low cost and mission success for the program can be achieved through the early incorporation of operational factors into the design.

Introduction

The objective of this paper is to identify a modeling and assessment process that integrates the Operations and support (O&S) planning processes with the design definition, systems engineering, and integration disciplines.

The initial SEI architectures and mission concepts are being studied to expand our manned space exploration capability. A need exists to develop Integrated Logistics Support (ILS) analytical tools and assessment processes that determine the best approach to support the SEI mission from a design, operations, and cost aspect. The greatest challenge to the SEI program is not only to get to the Moon and Mars but to maintain an operational capability over an extended period of time. If not accurately predicted, maintenance demands, equipment failures, and wearout may prevent achievement of operational goals established early in the program. It is a requirement for the SEI community to develop analytical models that quantatively estimate or predict support data and requirements at a very high confidence level. Through the use of historical operations and support data it is our premise that quantitative modeling techniques, based on empirical data gathered from a wide range of systems and environments, can be developed and applied to the SEI program. Many of the support requirements encountered in military and civilian desert and polar support sites are a prime source of data for the analytical models.

O&S requirements for the SEI program are substantial. Four areas of O&S require the development of large infrastructures to maintain an operational capability. These are Earth, orbital (including transfer), lunar, and martian support locations. Sustaining O&S capabilities for the entire SEI infrastructure will require manpower and material resources at a scale never before seen in our space exploration history. To assure system availability goals are achieved, these manpower and material resources must be distributed among the various defined nodes. Each node presents a unique set of constraints and requirements relative to support policies and support system design.

The Earth infrastructure has the continuous challenge of maintaining a capability to integrate and launch a massive amount of resources that are required to meet mission needs of the other nodes. Scheduling, manifesting, moving, and storing of assets at the launch center requires an elaborate inventory management system, along with the acquisition of facilities and warehouses to handle the launch vehicles, support systems, and payloads.

The orbital/transfer infrastructure will require a capability to assemble, service, test/checkout, and operate the designated systems that support the SEI activity. This includes the orbiting space station, its facilities, personnel, equipment ,and expendables.

The lunar infrastructure is distinguished by its low gravity (approximately 1/6 of Earth), and temperature extremes (approximately -240°F to +240°F). The surface soils, acting as an abrasive on moving parts, are a major consideration in determining design and support requirements on machinery and solar energy panels. Transportation and personnel movements on the surface requires high reliability and easily maintainable systems that can be supported by extravehicular activity (EVA) operations. The assessments of these systems requires development of an O&S earth based demonstration capability to assure achievement of all lunar O&S criteria.

Key lunar O&S trades and analyses requires: 1) Assessment of robotic systems in support of operations activities and development of their respective support resources using reliability and maintainability analyses, 2) Assessment O&S requirements for operational facilities, equipment, and supplies based on weight, complexity, and crew capabilities, 3) Estimates of maintenance and service requirements on all systems and subsystems to determine optimum spares and repair requirements and levels, 4) Assessment of O&S safety criteria on selected mission requirements and associated system usages, 5) Determination or selection of long term operational systems with extended duty cycles, and 6) Assessment of human factors to determine interfaces requirements.

The martian distance and environment will require the most dynamic and autonomous effort ever undertaken for a manned space mission. The challenges of long term habitation in a hostile environment and the long logistics line requires unique support requirements. Crew and equipment must be able to withstand the high winds, blowing dust, and extreme cold. Operational vehicle and system designs must also control contamination during surface operations to preclude the possibility of introducing bacterial material which may impact future scientific studies. Temperatures of approximately -205°F to +60°F impacts vehicle designs and O&S capabilities.

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Each activity of the lunar and martian operation requires the development of detailed functional flows that drive out O&S requirements. Based on the initial ground rules and selected architectures, operations processes, support requirements, and expendable resource needs will be developed. Key elements of the functional flows include; landing, crew/equipment deployment, facilities construction and setup, operations management, crew activities, equipment operation, transportation, maintenance, site survey, laboratory and science experimentation, equipment and material processing, industrial engineering activities, and communications.

Challenges

The SEI program will face many O&S challenges. These challenges begin during the concept development phase and continue throughout the design and development phases and into the systems operational period. Facilitization, operation, and maintenance at each SEI node requires extensive planning to meet specific mission objectives.

From the ground operations and processing standpoint the greatest challenge will be to control the large influx of materials and equipment to meet the operational and mission requirements. Figure 1 illustrates the ground processing activities that occur at KSC during a typical SEI mission. The arrows represent the couping between operations and are not directional. Control of resources, performance of verification/validation or checkout/test, and routine processing of payloads to orbit requires a carefully laid plan to accommodate such a complex operation. New vehicle studies are now in work to reduce the choke points that are illustrated in the drawing. If new vehicle designs can not be processed or integrated by some other means the vehicle assemble building (VAB) will clearly be the primary choke point for all planning activities.

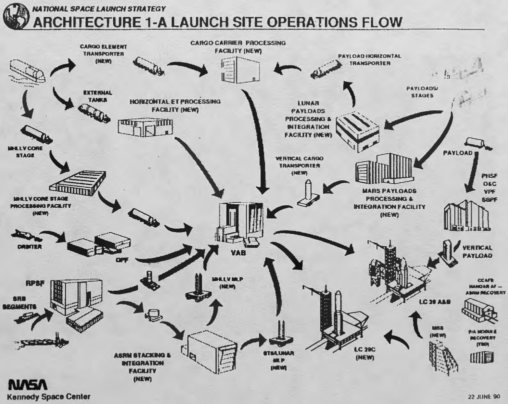

Figure 1. Ground Processing Operations for Lunar and Mars Projects Requires Multiple Support Processing Flows

Establishment of a permanently manned support base on the lunar surface has many O&S challenges. Development of safe, habitable, and flexible facilities will require many resources normally found at remote military sites. Figure 2 depicts a mature lunar support facility that provides a shirt sleeve environment to support operations after a large operating industrial site has been established. The uniqueness of the site requires the establishment of analytical O&S models that address the hostile environment and provide the necessary support assessments to assure continued operation. The ILS planning team, as part of the O&S activity is challenged to accurately identify and quantify total support requirements for the facilities. This includes lighting, power systems, communications, medical, clean rooms, heavy and light equipment maintenance, life support systems, pressure systems, etc.

Operational systems will also require accurate support predictions for maintenance and spares requirements. Most designs developed from "allocated reliability values" may not meet the specific requirements effectively. This is mainly due to the lack of "bottoms-up" data since each selected system/subsystem design has not been developed at the piece part level. The use of historical data that can be factored into hard estimates of the systems capability (operations, mean-time-between-failure, mean-time-to-repair, reliability, etc.) can be more beneficial in assessing a design during the definition phase. Once the design has been developed, bottoms-up data can be used to verify the predicted values.

FLUOR DANIEL CONCEPTUAL DESIGN

Figure 2. Mature Lunar Support Center Provides Shirt-sleeve Environment for Accomplishing Multiple Base Functions and Operations

The Mars base establishment will evolve from a small facility as illustrated in Figure 3 into a full operational base much like the plans for a lunar facility. The same data is required from the O&S assessment team. When making support estimates, the long trip of 9+ months from Earth must be included in determining the quantity of resources to be delivered during the initial phases of the project.

The key challenge is to assure that system operations can be sustained during a crew visit. Specific models must evaluate each system at a detailed level early in the design definition phase. Much of the O&S assessment data can be developed using military and polar expedition information as a baseline. This allows us to compare estimated values when developing operational requirements. One of the major inputs could come from chemical, biological, and radiological (CBR) data that is used in fielding military personnel. The CBR planning (basically applied in reverse for martian operations) could be used to meet specific crew needs for safe, clean, uncontaminated atmospheric operations.

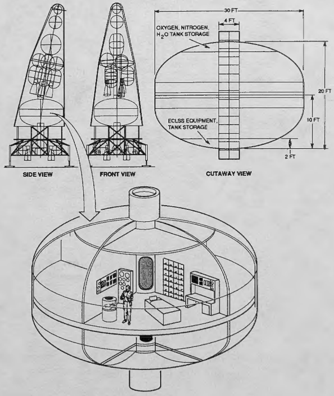

Figure 3. Early Mars Base Requires Special Planning to Support Operational Requirements and Personnel

Consideration should also be given to the development of low maintenance, high reliability operational equipment and handling systems in support of lunar and martian surface operations. One example of reducing support costs, while gaining a more reliable system, is to use robotically controlled vehicles as depicted in Figure 4. This Winch Cart Robot (WCR) has been prototyped at Rockwell and is now undergoing evaluation and engineering tests. The small, simple winch cart (approximately 3 feet high, 3.5 feet wide, and 5 feet long) can be the prime mover for all construction, mining and transportation requirements. A small number of these multipurpose vehicles virtually guarantees a continuous capability and reduces the number of unique spares requirements. The inherent compactness of the winch cart permits shirt sleeve maintenance in the small habitation and laboratory modules of the early bases.

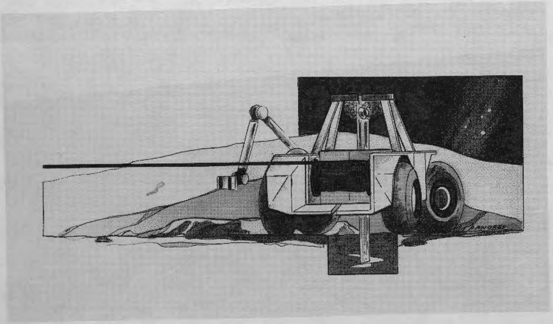

Figure 4. Winch Cart Robot (WCR) Offers Less Complex System to Support Mining and Simple Surface Operations

When conducting surface operations away from a base facility the EVA capability must be supportable for longer durations than typically encountered by the current Shuttle program. Figure 5 illustrates a typical mission that an EVA team would perform on the lunar surface (NASA Ames Research Center concept). The longer duration missions will require new suit technologies to prolong the useful life of the suit liners and gloves. The life support system must also be more supportable and possess system redundancies needed to meet these longer missions. O&S planning of the specific requirement requires coordinated planning with the current manned space team at Houston and the NASA suit development centers. Considering the nature of equipment utilization, predictive modeling of EVA maintainability and supportability characteristics must be based on extremely reliable data with very high statistical correlations.

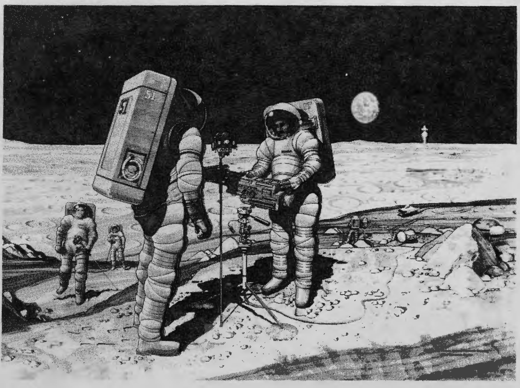

Figure 5. EVA System Must be Highly Reliable and Resilient to Lunar and Mars Environments.

An ILS assessment process must be developed in order to determine and refine support requirements for the SEI infrastructure and nodal facilities throughout the program life. The process must include analytical methods and models to determine impacts on: 1) initial designs relative to maintenance demand, timelines, predicted failure rates, and special support requirements, and 2) ground, node, and lunar/planetary operations concepts.

The performance of these assessments will require analytical tools that are capable of evaluating the entire spectrum of support requirements at each facility (including ground operations), and must provide programmatic requirements data as well. Modeling and assessment techniques are being used by the space community to define ILS requirements for any specified architecture. The use of testable, demonstratable, and verifiable analytical models assures that operational life cycles, programmatic costs, turnaround activities, and support resources are measured accurately (within a specified confidence limit).

Scope of Operational Support Concepts

Basically there are three operations areas requiring O&S for the SEI program. These are: 1) ground including flight/mission operations, 2) nodal and orbital transfer operations (with complex assembly, service, and flight operations, and 3) lunar or martian surface operations.

The ground and mission operations activity is the first major operations and ILS node that requires development of robust transportation, operations processing, and warehousing requirements. The use of KSC facilities and resources to store individual mission kits and major flight articles requires precise timing to reduce the "glutting" effect of multiple mission support activities with limited facilities and personnel resources . "Just-in-time" planning for deliveries of assets to KSC requires a new support approach within the NASA community. The normal approach to space system processing has been to deliver the assets as soon as possible.

Modeling Techniques

O&S capability analytical tools and models for the SEI program are being developed by:

1. Using applicable commercial off-the-shelf tools (referred to as "tools-for-design), and tailored maintenance support and resource assessment models.

2. Continuing development of operational support functional flows at each node, depicting processing functions, O&S resource requirements, and facilities.

3. Providing quantitative empirical data and general support requirements associated with similar systems and analogous operating environments (which includes facilities, personnel, repair, spares, procedures, and support equipment).

Modeling Results

Our current IR&D O&S efforts have concentrated on the development of analytical tools and models that can accurately predict support requirements for each system and subsystem within a specific architecture. We now have the capability to estimate subsystem failures (within a confidence level of greater than 90 percent on most subsystems) and maintenance task times that drive spares and repair estimating techniques. Based on these estimates our use of commercial tools to analyze specific architectures and develop ILS requirements to the appropriate level of support can be extremely useful during the design definition phase of the program. We have used these tools successfully for the Advanced Manned Launch System/Personnel Launch System studies for the NASA Langley Research Center (LaRC).

We have also applied these tools to:

1. Assess proposed Shuttle modifications to determine return on investment of the proposed change.

2. Estimate Assured Crew Return Vehicle (ACRV) reliability and maintenance requirements.

3. Predict Space Station Freedom assembly and maintenance support requirements

4. Estimate support requirements for various satellite and space systems associated with DOD programs.

Applications

As stated above, our modeling capabilities address O&S concerns during the early design definition phases of any program. The use of traceable maintenance and failure information in development of our models provides us with a more confident prediction. This allows us to impact the designs prior to their detailed development (when its becomes to costly to make a change to meet some operational requirements).

Acronyms

ACRV	Assured Crew Return Vehicle
CBR	Chemical, biological, radiological
DOD	Department of Defense
EVA	Extravehicular Activity
ILS	Integrated Logistics Support
KSC	Kennedy Space Center
LaRC	Langley Research Center
MTBF	Mean-time-between-failure
MTBR	Mean-time-between-removal
O&S	Operations and Support
SEI	Space Exploration Initiative
VAB	Vehicle Assembly Building
WCR	Winch Cart Robot

References

NASA KSC briefing to: National Space Council, June 22, 1990 - Space Launch Strategy Working Group

NASA KSC Space Exploration Initiative Working Group - Operations Concept Review, Launch and Recovery Concepts/Integrated Logistics, January, 1991